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FINAL REPORT OF RESEARCH CONTRACT N00014-67-A-0239-0019, (U)  
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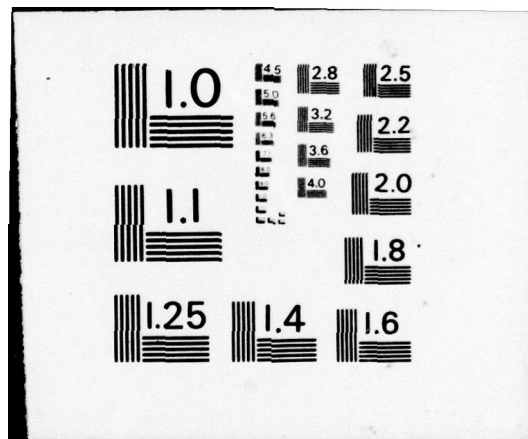
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Division of Mathematical and Physical  
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*409965*

5 November 1976

Gentlemen:

Enclosed please find the Final Report of Research Contract  
N00014-67-A-0239-0019, funded by the Office of Naval Research.

Sincerely,

*Angelo Bardasis*

Angelo Bardasis  
Associate Professor of Physics

/pak

distributed to:

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## FINAL REPORT

*Letter on file*

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Under Research Contract N00014-67-A-0239-0019 work was performed in the following areas:

### A. PHASE TRANSITIONS

#### 1. Ising Model

The continuum formulation of the two-dimensional Ising model has been applied to the calculation of the spin-spin correlation function. This involved a non-linear function of the occupation number operators for the lattice sites located between the two points of correlation. This problem has been found to be mathematically analogous to the problem of the X-ray absorption threshold in the degenerate Fermi gas.

#### 2. Screening Theory

Considerable effort has been devoted to finding a satisfactory approximation for the order parameter-order parameter correlation function. Dispersion theory has been developed for fitting phenomenologically the experimental data. This method is powerful in that it automatically takes into account threshold and positive definiteness conditions. These conditions were studied in the screening approximation leading to a general phenomenological framework. The treatment has been applied to the dimensionality  $D=2$  (Ising model) and  $D \rightarrow 4$ . Known results in these limiting cases serve to check the method and bracket the desired  $D=3$  case. The problem of finding an accurate approximation to the  $D=3$  correlation function, at least for a scalar field along the "critical isochore" can be regarded as solved.

The phase transition problem is mathematically equivalent to non-linear field theory, and no solution exists in closed form for the problem in its

most general form of arbitrary space dimensionality  $D$  and order parameter dimensionality  $n$ . The so-called " $\epsilon$ -expansion" of Wilson uses  $D=4$  as a starting point since this is a special case where the problem is solvable. A solution is developed in powers of  $\epsilon=4-D$ . We have employed the alternative approach of the screening approximation, based on an  $n^{-1}$ -expansion. The coefficient  $\eta_2(D)$  in the expansion of the critical exponent  $\eta = n^{-1}\eta_1(D) + n^{-2}\eta_2(D) + \dots$  was calculated by Abe for  $D=3$ . We extended the calculation to arbitrary  $D$  and found a kind of oscillatory behavior of the function  $\eta_2(D)$  in the interval  $2 \leq D \leq 4$ , with a zero at approximately  $D=2.87$ . This behavior is consistent with the expectation that the  $n^{-1}$  expansion is not a convergent Taylor's series, but only an asymptotic expansion. We have demonstrated this in detail for the zero-dimensional model where all of the terms can be exhibited explicitly. In the  $D \rightarrow 2$  limit we found that  $\eta_2(D)$  vanishes as  $2n^{-(D-2)}$  in agreement with the formula  $\eta_2(D) \sim (D-2)/(n-2)$ , found by Migdal in a different way.

### 3. Binary Liquid

The physical picture justifying the decoupling approximation for the binary liquid is that the Brownian motion in the hydrodynamic shear modes carries along the concentration fluctuations. The latter thus participate in a kind of random walk and, to a good approximation, do not affect the shear modes. Concentration fluctuations occupy regions of the liquid of the size of the correlation length  $\xi(T) \propto (T-T_c)^{-\nu}$  so that the diffusion coefficient  $D(T) \propto \frac{1}{\xi(T)\eta(T)} \propto (T-T_c)^\nu$  where  $\eta(T)$  is the hydrodynamic shear viscosity. This requires  $\eta(T)$  to have no temperature dependence. In fact, experimental and theoretical work indicates that  $\eta(T)$  does show a weak singularity in  $T \rightarrow T_c$ . Our work indicates that  $\eta(T)$  is of the form  $\xi(T) = A \ln \xi(T) + B$ .

## B. RESISTIVITY IN FERROMAGNETS

We have developed calculations associated with the low temperature resistivity due to electron-paramagnon scattering in nearly ferromagnetic materials. The process considered is one in which the incident s-electron carrier is scattered into a d-state (as opposed to the usually considered) s-state with the creation of a paramagnon. Multiple scattering suffered by the scattered d-electron with the d-electron constituting part of the paramagnon has been handled by the t-matrix approximation. The results are appreciable in those cases involving paramagnetic alloys.

## C. FAR INFRARED STUDIES OF NARROW BAND GAP SEMICONDUCTORS AND SEMIMETALS

Alloys of the  $\text{Pb}_{1-x}\text{Sn}_x\text{Te}$  type have low TO phonon modes, large static dielectric constants, small energy gaps, and small effective masses. These properties of this type of system make it interesting both for device applications and for basic research potential.

Experiments on the reflectivity of PbTe reveal a dielectric anomaly near 50 kG associated with the cut-off of propagating magneto-plasma waves. The line shape of this anomaly has a complex structure which is inconsistent with the magneto-conductivity function proposed for PbTe. We explain this structure by considering a two-particle interaction mechanism with low lying optical phonon modes. In other words, the effect of an electron-phonon interaction is to create an exciton-like entity. (In PbTe the static dielectric constant is sufficiently large so that the Coulomb interaction would be so diminished as to preclude the formation of the usual type of exciton). Preliminary computer solutions to the resulting set of coupled integral equations for the exciton-like wave functions indicate the validity of this approach.

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Co-Principal Investigators

26 October 1976